PRIVATE AND CONFIDENTIAL

RESEARCH DEPARTMENT

The impact of users' needs on the design of data processing systems

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THE BRITISH BROADCASTING CORPORATION
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1. INTRODUCTION

The conference was held at the Heriot-Watt College, Edinburgh, from 31st March to 3rd April 1964. It was organized jointly by the British Computer Society, the British Institution of Radio Engineers and the Institution of Electrical Engineers, under the aegis of the United Kingdom Automation Council.

Over six hundred people attended the conference. Their affiliations were well distributed over the fields of computer manufacture, scientific research and commerce. This was the first time in the United Kingdom that a conference had been organized to present papers and to provide opportunity for discussion on the relations between users, programmers and engineers in their common aim of providing efficient data processing systems.

The conference papers were divided into four main categories:

(a) Programming and Operating Systems
(b) Storage Technology and Organization
(c) Maintenance
(d) Input, Output and Man-Machine Communications

All the papers were published a week before the conference began and the sessions followed the rapporteur system of presentation. Each rapporteur presented a comprehensive synthesis of the papers in his session, occasionally introducing other aspects to promote discussion. The adoption of this system enabled the conference participants to discuss forty papers with their authors in only three one-day sessions.

Several technical visits and social events were arranged. They will be described in Section 4.

The rapid development of the computer field has brought with it a certain amount of inescapable jargon. Two words which appear to have been widely accepted are "hardware" and "software". The former word is used to describe the electronic circuits and electro-mechanical equipment of a computer. The latter word contrasts the hardware with the programming which is needed to organize the equipment into a versatile computing system. The word "word" itself has a special meaning in the context of computers. Generally it refers to the binary digits (bits) grouped into one store location which is specified by a reference number. Usually one number or two computer instructions are contained within the "word".

2. INTRODUCTORY SESSION

The opening address was given by Sir Edward Playfair, President of the British Computer Society.[1]

Sir Edward forecast that in the next decade most problems in communication with computers will be solved, but that efficient integrated data processing systems are still a long way off. Small computers should not be replaced by large computers. The two should be complementary. Individual units of computer hardware are becoming faster in operation and more reliable, but their organization into systems by means of computer programming and physical connections is not matching this progress.

Probably the most difficult problems confronting computer engineers are those of fast data input and output and man-machine communications. Pattern recognition in man is not yet fully understood. This is one reason why it is difficult to devise machines which can read printed characters into computers.

Sir Edward concluded by stressing the need to familiarize the older generation of potential users with the fundamentally simple nature of computers, and he appealed for a wider mathematical education for the arts man.

3. THE PAPERS

The salient features of those papers and discussions which might be of interest to the BBC will now be presented. It should be noted that the conference was concerned with digital data processing and, therefore, with digital computers.

Session 1: Users' Needs

The two papers in this session were written from the standpoint of the user with a very large amount of commercial work obviously suitable for computers. The accent was upon costs, reliability and operating efficiency. It was assumed that "large" computers will continue to be better value than small ones, and, therefore, that the best policy for the user is to employ the "biggest" computer that can be both fully loaded and efficiently managed.

Computer faults are usually in the electro-mechanical peripheral devices such as paper tape punches, magnetic tape units, etc. The widely held view that much more attention should be given by manufacturers to the reliability of these devices was re-iterated. In practice it becomes necessary to break down long computations into sequential short runs during which the peripheral devices may be expected to function normally.

One author referred to the practice of "time-sharing", i.e. the concurrent processing of several programmes, as an inferior solution to the problem of keeping a fast central processer busy when it is fed by relatively slow peripheral transfer units. From the commercial viewpoint he felt that this idea could not be extended very far before computer management difficulties would arise. He suggested that a better answer would be to raise the maximum data transfer rates for magnetic tape units up to about 300,000 characters per second.

Another author also recognised that although an intricate scheme of time-sharing, achieved partly by hardware and partly by programming, can allow the central processer to be shared between several independent programmes and can afford concurrent operation of many peripheral input-output devices, considerable organizational complication is introduced. He thought that this complication was justified by the expectation that it will be cheaper to divide one large fast computer between interleaved programmes than to use several smaller slower ones each working independently on a single programme. This largely remains to be proved under field conditions.

The use of small machines for small jobs was advocated, but small machines should be able to be coupled together to carry out truly parallel processing of large jobs. In this way the machine could be made to match the job and not vice versa. Also, with several linked computers a fault in any one of them need not hold up all computation in the system. The complications and risks of a single large machine should be restricted to those processes for which it is essential.

The BBC does not possess a large computer at the moment and therefore several points raised in this session are not of immediate interest. However the idea of coupling several small computers together to form a reliable system may have relevance if a second Elliott 803 is purchased.

Session 2: Programme and Operating Systems 1 (Interaction with Users' Needs)

The first paper discussed two broad types of computer language. One, "Language X", comprised a complex inflexible scheme resulting in a compiler which could translate almost "clear" language and algebraic functions into machine code. It was suggested that Language X was more suited to big commercial jobs designed for large and fast computers where there would be adequate storage for the compiler. "Language Y" typified a less comprehensive but more flexible scheme embodying a more restricted set of arithmetic expressions and no complex logical instructions. Language X would normally be quite unsuitable for a small computer such as the Elliott 803. Here the smaller non-recurrent commercial jobs would be written in Language Y and the store need not be dominated by the translator.

When certain arithmetical functions are not used, or repeated operations on operands in fixed store locations occur, parts of certain programme instructions become redundant. One author discussed approaches to making available a systematic curtailment of instruction dependent upon programme requirements. Faster calculation and less use of store locations would result.

An example was given of the way in which users can influence the computer manufacturers in the provision of programme languages. The FACT language, available on Honeywell H800 machines, translates almost "clear" language into machine code instructions. When two H800 machines were supplied to a certain group of users the language was not fully tested and the group was able to feed back user's requirements to the compiler writers. This resulted in a considerable improvement in the efficiency of FACT programmes. As active members of the Elliott 803 Users' Group, the BBC can similarly pass back criticisms and suggestions regarding the 803 Programme Library.

In a paper discussing the desirable computing facilities for a College of Advanced Technology, it was pointed out that time-sharing could make it possible for normal programmes to be interleaved with computations that controlled experimental apparatus via digital-to-analogue converters. If the BBC were to possess a large computer, similar facilities could allow procedures such as transmission line testing and switching to be controlled by the computer.

Session 3: Programme and Operating Systems II (Compiling and Operating Systems)

The papers in this session dealt with several methods of decreasing the time spent on programming and running a given computation on a given machine, and with the efficient management of large machines.

A paper on the operation of large machines at the Atomic Weapons Research Establishment discussed the value of linking remote data collection sites to a central computer via transmission lines. The faster the machine the faster the data transmission rate should be. For the Elliott 803 system a teleprinter link is adequate, but for larger and faster machines such as the Elliott 503 a wider bandwidth telegraph link or even a magnetic-tape data link would be more appropriate.

Several papers referred to time-sharing facilities, and one gave a particularly clear account of the general features of a comprehensive monitor programme affording time-sharing and other facilities on the I.C.T. Orion computer. In view of the possibility of the BBC requiring a large machine in a few years' time it is worth summarizing this latter paper as an example of what facilities might be available on such a machine. An account was given of the way in which time-sharing is organized on Orion computers by the Orion monitor programme (OMP) and certain special pieces of hardware.

Apart from the usual facility for peripheral data transfers being simultaneous with computing, several programmes can be run concurrently without the need for writing time-sharing instructions into them. The frequency of interruptions in any one programme varies between one and a hundred times a second, and the time spent in the time-sharer section of OMP is only about 1% of the total computing time. Given a reasonably diverse set of programmes, the central processer and the peripheral devices are kept continually busy. An interesting point raised here was that any programme error which leads to an attempted violation of reserved store causes time-sharing to be stopped until the reservation settings are changed or confirmed by the operator.

OMP allows messages to be input and output via a typewriter so that special action can be taken quickly in the event of a hold-up. Programme testing is well organized. Monitoring can be arranged independently on several types of event in several concurrent programmes in several different "styles". For example, jump (transfer) instructions can be monitored continuously, checked in groups of 16 correct jumps, or checked for correct entry to subroutines.

The hardware incorporates a digital clock giving the time to the nearest second. This is printed out every minute. Messages associated with the start and finish of jobs always bear a time marker so that the programme running time can easily be deduced. Further, the actual time spent by each individual programme in the central processer is registered. One of the special features of the system is a means of interrupting a programme for examination when it has spent more time in the central processer than was estimated.

Session 4: Programme and Operating Systems III (Implications on Machine Design)

Several authors contended that more consideration of the programming languages to be used on a computer should be given at the stage of designing the hardware. For example, Algol[2] is a valuable and comprehensive language which unfortunately needs certain slow-acting programmes to match it to the hardware of conventional computers. One author described how a special machine code was evolved to allow for the provision of Algol on the Elliott 803 without the need for unacceptable usage of the relatively small magnetic core store.

Session 6: Maintenance

This session was devoted to methods of maintaining a computing service at a computer centre whether there be one or several central processing units available.

A diagnostic test programme for Orion computers was described. It represented a class of maintenance techniques which can be of great assistance in fault diagnosis provided that the fault coverage is comprehensive. In this particular case 2623 computer elements could be tested, and there were 1566 different fault indicators ("stops"). Similar test programmes are used on the BBC's 803.

One paper clearly demonstrated the value of collecting fault statistics from all users of a particular type of equipment. In the example given the mean time between failures in a particular data processing system was quickly doubled, both in the existing units and in those in service, by virtue of rapid computer analysis of users' maintenance dockets which were in punched-card form.

The author of the final paper in this session put forward four main factors likely to affect the future of maintenance of data processing installations:

(1) The increasing reliability of electronic circuits
(2) The design effort directed towards greater reliability and maintainability of mechanical equipment
(3) The increasing number of small computers
(4) The use of the computer itself in scheduling maintenance and diagnosing the cause of troubles

The author contended that these factors would set the trend away from having resident maintenance teams at individual computer installations. Instead, there would be maintenance services provided by a mobile team of experts. Several conference delegates expressed the view that it would be difficult to organize highly skilled and experienced engineers into "flying-squad" maintenance teams because of the unwillingness of such grades of personnel to be "on call" for long-distance jobs at short notice. It is an unfortunate fact that it is usually the unscheduled corrective maintenance which calls for the greatest degree of skill with computer installations.

Session 7: Input/Output

The first paper in this session gave a quite detailed account of the factors which must be considered when setting down a Print Specification for use with reflected-light reading machines. This type of machine scans the document to be read with a small spot of light and converts variations in the reflected light into electrical pulses. A versatile reading machine would have many applications within the BBC. For example, the intermediate stage of Audience Research survey data in the form of punched paper tape could be eliminated.

The attachment of two high-speed on-line devices to the London University Atlas 1 computer was described. The first of these was the Hough-Powell Device (H.P.D.) which line-scans photographs of tracks in a bubble chamber fed by a particle accelerator, and outputs the loci of tracks in digital form at an average of about 15,000 pairs of co-ordinates per second. The number of photographs per experiment can run into tens of thousands so that magnetic tape storage, the apparent alternative to on-line working, is impractical because a whole magnetic tape would be filled every few minutes. Atlas is equipped with a dynamic storage allocation system which affords a switching time between programmes of about 1 ms and which makes efficient use of the fast access magnetic core store by temporarily dumping dormant programmes on to magnetic drum stores. The H.P.D. digitizings which occur during the programme switching time and the interval between calls for the H.P.D. computer programme (perhaps 60 ms) are stored in a buffer core store. The second high-speed device is part of an Adaptive Control Experiment at Imperial College and it is linked to the Atlas by video frequency cable. The equipment generates 60,000 bits per second and requires 48,000 bits per second back from the computer as control instructions. Buffer stores on both input and output are again used to expedite asynchronous working between the experiment and the computer.

Although the two examples given concern continuously operating devices, the automatic storage allocation on Atlas affords efficient use of the processer even when on-line devices with infrequent calls for programme running are connected to it. For example, the system could be used for direct communication between programmer and programme, a technique which assists the quick development of programmes. Most aspects of the interaction between the computer, the programmer and the controlled apparatus in these examples are relevant to the problem of organizing a large computer to cater efficiently for the diverse applications it would have within the BBC.

The way in which an IBM 1401 is being used to store and analyse the state of all the major items of equipment owned by the Central Electricity Generating Board was described in considerable detail. Examples were given of the data forms which have to be filled in by technicians who are not necessarily conversant with data processing systems.

Another example of a data preparation system was given by an author who pointed out that the very wide speed range of cathode ray oscilloscope photographs leads to a versatile means of recording fast transient electrical phenomena. However, the problem of converting the photographed information into a form which can be processed by a digital computer calls for quite ingenious instruments if the conversion is to be rapid and reasonably accurate.

An automatic film reader was described that circumvented the 2% to 5% deflection inaccuracy of automatic film readers using flying-spot scanner systems by referring the spot to a precision graticule scanned simultaneously in a separate optical path. The graticule pulses are counted and the count is stopped when the spot crosses the trace on the film record. The X and Y co-ordinates given by the X and Y graticule pulse count are then stored in a small core store prior to being transferred to magnetic tape for processing. The co-ordinates found in this way were resolved to about 0.2% in Y and 0.4% in X and one complete transient could be scanned in 5 to 10 seconds.

The day-to-day handling of computer data in I.C.I. where the distribution of staff calls for remote computing facilities was described. The author pointed out the ease with which data can be telegraphed over conventional communication channels when the computer input medium is paper-tape, and he stressed the need for medium-priced, medium-speed printers which were compatible with the data transmission rate readily available over telephone channels. The problem of supplanting analogue recorders with the more expensive digital recorders was discussed. The author felt that for some years to come analogue recorders would be retained, and that trace-reading machines would continue to be used to convert the information to digital form for computer processing. He favoured either time-shared computers or satellite computers.to allow rapid programme development and correction without interference with the timing of production runs. The build-up of a well documented programme library was of prime importance in avoiding unnecessary new programming work. All the points are of direct interest to a potential user of a large computer.

Session 8: Panel Discussion

Panel:	A.S. Douglas Basil de Ferranti C.R. Smith M.V. Wilkes
Chairman:	W.S. Elliott

The discussion was a fairly light-hearted affair with the panel answering impromptu general questions from the Chairman and the floor. No point was dealt with in great depth or detail, but one salient opinion of the panel members was that the development of central computer hardware was about two years in advance of the development of peripheral equipment, input-output systems and efficient computer management.

Session 9: Man-Machine Communications

The first paper set out some of the objectives of time-sharing on computers and suggested ways in which these could be achieved. It is recognized that a more efficient use should be made of the human user in relation to the computer. The problem arises in such places as an engineering design office, where several users may require only short calculations to be performed, with time to consider the next step before using the computer again. The system envisaged is that in which a large number of users are on-line to the computer via consoles or typewriter keyboards. It is suggested that for a large number of users, say several hundred, the use of a small general-purpose computer to act as a buffer would be advisable. The basic idea is that each user would be able to insert programmes and data, to test, run and modify such programmes, and have results back within a few seconds, assuming that the computing time is short. This means that the computer used must have a large memory, not all of which need be high speed but the high-speed portion of which should have a capacity of between one hundred thousand and a million words.

As part of this session, a demonstration was given of the working of Project MAC at M.I.T. The system is based on the use of two IBM 7094 computers with nine million word magnetic disc stores. The system used is such that each user is allocated 120 ms of computer time in turn. If there is a hold-up for any reason - end of calculation, error, further instructions required, etc. - the supervisor programme moves the process to the next user and so on. The demonstration took the form of a teleprinter keyboard at the conference linked by Telex to the computer in M.I.T. A simple programme was typed on the keyboard together with the appropriate control instructions. The results were printed up on the teleprinter within seconds of the start command. To the user, this was "his computer". It was learnt afterwards that five other users were making use of the computer at the same time. This was a very convincing demonstration.

In the early days of computing, the programmer was often on-line with the computer. The computer was then used inefficiently. When time became scarce, the programmer had to do his corrections away from the computer, and so the programmer was used inefficiently. With time-sharing it is hoped to bring about a compromise so that both computer and programmer are used efficiently.

4. TECHNICAL VISITS AND SOCIAL EVENTS

Several visits to local laboratories and factories took place during the conference. They served to illustrate in practical terms the way in which research and development organizations are utilising digital data processing systems. In particular, the astronomical and seismographic equipment of the Royal Observatory of Edinburgh incorporated several ingenious devices for digital data preparation from unusual sources. These included a star-map plotter and a system which prepared magnetic tapes of seismograph data from remote locations for direct input to an Atlas Computer.[3] The data link from the Edinburgh University Computing Laboratory to the Manchester University Atlas was also demonstrated. The link used one telephone channel and was not on-line to the computer itself.

There were also visits to the Ferranti Automatic Machine Tool Factory at Dalkeith, and to the National Coal Board's computing centre at Sighthill.

In addition to the organized programme, a visit was made to the Department of Phonetics, Edinburgh University, by courtesy of Professor D. Abercrombie. That Department has for some years been developing a Parametric Artificial Talking Machine (P.A.T.) from the original design by Dr. W. Lawrence of S.R.D.E., Christchurch.[4,5] An experienced phonetician analyses a sonagram of a particular speaker (usually produced on a Kay Sonagraph) and produces a "programme" of the observed variations with time of up to eight basic speech parameters (pitch, formant frequencies, etc.) The programme is then fed into the machine to give dynamic control over the eight speech parameters which are generated internally and which combine to produce a good reproduction of the speaker's voice.

The social events included a civic reception, a conference dinner and a ladies' programme.

5. CONCLUSIONS

It was rather difficult to draw many conclusions of direct interest to the Corporation since, in general, the papers were dealing with very large, very high-speed data processing systems which the Corporation does not possess at the moment.

However, there were several general points to note. Sir Edward Playfair in the opening address drew attention to a growing gap in the ability of the policy maker and the computer "operator" to communicate with one another. This point was stressed on several occasions.

Another general plea was for the speed and reliability of peripheral devices to be brought more into line with those of the central processers. More effort is needed in this direction to enable full use of the present central processing equipment to be made without consideration for the next generation of central processers.

Particular points felt to be of more direct interest to the Corporation included the possibility of forming a pool of several computers of one type (belonging to several users) and the employment of a full time engineer to maintain them. It was suggested that a pool of twelve computers could provide ten users with about two years' service free from breakdowns.

Perhaps the most significant point was that suggested by the Project MAC demonstration and some of the papers on the control of equipment by computer. If thought is to be given to the use of a large central computer in the Corporation, perhaps with equipment control applications, then it is suggested that the ideas of Project MAC should be considered as a means of providing many different users with effectively the sole use of such a computer.

A second way of utilising a large computer would be to have one or more small computers as buffers either on-line or, more probably, as a means of preparing data which would then be transferred on magnetic tape or film. Both schemes would require the computers to be compatible. In view of the existence of one small computer within the Corporation, the latter method may well be the better solution since a considerable amount of work could still be carried out using the small computer in its own right.

The bottleneck caused by the time taken to prepare data in large data processing systems was stressed by several people. Considerable saving in both time and effort could be effected if the chain comprising data - written form of data - punched form of data could be shortened. In Research Department there are several devices which output their data in punched paper tape form, namely the mains frequency recorder, field strength recorders and the audio-frequency analogue-to-digital converter system under development. Also, thought is being given to the use of a Trace Analyser which produces co-ordinates on punched paper tape.

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